with all good wishes.
Kenneth L. Smoke

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Psychological Monographs

An Objective Study of Concept Formation

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An Objective Study of Concept Formation

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CHAPTER I

Introduction

This study was offered in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Ohio State University in 1931. The work was carried on during the writer's residence as a University Fellow.

The history of experimental psychology, like the history of experimentation in any field, is for the most part the story of the attack upon the more and more subtle, the increasingly complex. Making its appearance at a time when the idea that the complex grows out of the relatively simple was getting a grip upon the scientific world, the infant science quite naturally turned to problems that seemed to give promise of immediate solution rather than to those that fell within the mystic realm of the "higher mental processes."

From ancient times it had been traditional for philosophers and others to eulogize "Reason," the highest of all the faculties. But, as is so often the case, the amount written and spoken was inversely proportional to the knowledge at hand. With our own century, however, there came a rather widespread effort to deal with these "higher reaches of the mind" in a laboratory. The first decade was rich in experiments of this sort.

A number of these studies dealt in one way or another with the processes of abstraction and of concept formation (or generalization).[1] Miss Fisher, who herself carried out one of the most exhaustive investigations along these lines, gives a bibliography and an admirable account of this early work.[2] All of these investigators employed an introspective technique. For

[1] We are using these two phrases as synonyms. We employ "concept formation" because most readers are probably more familiar with it than with "generalization," and because "generalization" is sometimes used as synonymous with "principle" or "law."

[2] Fisher, Sara Carolyn. The process of generalizing abstraction; and its product, the general concept. *Psychological Monographs,* Vol. 21, No. 2, 1916. Pp. 213.

this reason their results are not relevant to the present undertaking.[3]

Since Miss Fisher's monograph there have appeared, in addition to several introspective studies, three reports of experimentation along these lines with which we shall concern ourselves, namely those of Hull,[4] Kuo,[5] and Gengerelli.[6] Like the present investigation, these studies involved the use of an objective technique.[7]

Hull's study is easily the most outstanding of these. Obviously it was a very careful piece of work, and, as its title suggests, emphasis was constantly placed upon quantification—certainly a most admirable trait. In our view, however, Hull misconceived entirely the nature of the process he was investigating. The title of his monograph should have been "Quantitative aspects of the process of abstraction," for in reality he did not study "the evolution of concepts." Viewed as a study of abstraction, Hull's monograph is perhaps the best thing we have. It is too well known to call for detailed treatment here. We shall discuss only those fundamental aspects of it which lead us to the conclusion that Hull did not do what he thought he was doing.

The whole of Hull's study was rooted and grounded in the doctrine that concept formation can be studied by presenting to a subject a series of visual stimulus patterns (Chinese characters, in the case in point) each of which has a "common element"[8] in the sense of containing "certain strokes in common" with the

[3] We have here neither the space nor the inclination to consider the validity of the technique of introspection. Suffice it to say that "experimental phenomenology" (as it is called in these latter days) simply does not yield answers to the educational—we use this term in the broadest possible sense—questions that cry aloud for an answer today. To follow this method in psychology is, at the least, to fiddle while Rome burns.

[4] Hull, Clark L. Quantitative aspects of the evolution of concepts. *Psychological Monographs*, Vol. 28, No. 1, 1920. Pp. 86.

[5] Kuo, Zing Yang. A behavioristic experiment in inductive inference. *Journal of Experimental Psychology*, 1923, 6, 247–293.

[6] Gengerelli, J. A. Mutual interference in the evolution of concepts. *American Journal of Psychology*, 1927, 38, 639–646.

[7] By an "objective technique" we mean one constructed according to the pattern of the natural sciences.

[8] This is Hull's phrase. See, for example, pages 15, 18, 19, 35, 41, 80, etc., of *op. cit.*

other members of its group. Hull is very explicit on the point at issue. In his account of the technique which he employed he writes, "*All of the individual experiences which require a given reaction must contain certain characteristics which are at the same time common to all members of the group requiring this reaction and which are NOT found in any members of the groups requiring different reactions.* This requirement is satisfied by the fact that all the characters (*e.g.* in Series A, Plate I), contain certain strokes in common. These characteristic strokes for each of the twelve reaction-groups are isolated in the vertical column of characters labeled 'concept.' They may be easily observed imbedded in each of the characters in the group following, but they are not found in any of the other groups." [9] It is our contention that if any concepts have ever been formed in any such fashion, they are very few in number. We confess our inability to think of a single one.

Perhaps an illustration will help to clarify the issue. Hull himself gives an admirable one.

"A young child finds himself in a certain situation, reacts to it by approach say, and hears it called 'dog.' After an indeterminate intervening period he finds himself in a somewhat different situation and hears that called 'dog.' Later he finds himself in a somewhat different situation still, and hears that called 'dog' also. Thus the process continues. The 'dog' experiences appear at irregular intervals. The appearances are thus unanticipated. They appear with no obvious label as to their essential nature. This precipitates at each new appearance a more or less acute *problem* as to the proper reaction. This problem largely monopolizes the focus of consciousness. Meantime the intervals between the 'dog' experiences are filled with all sorts of other absorbing experiences which are contributing to the formation of other concepts. At length the time arrives when the child has a 'meaning' for the word 'dog.' Upon examination this meaning is found to be actually a characteristic more or less common to all dogs and not common to cats, dolls, and 'teddy-bears.' But to the child the process of arriving at this meaning or concept has been largely unconscious. He has never said to himself, 'Lo! I shall proceed to discover the characteristics common to all dogs but not enjoyed by cats and "teddy-bears."' The formation of the concept has never been an end deliberately sought for itself. It has always been the means to an end—the supremely absorbing task of physical and social reaction and adjustment. Such in brief is our 'standard' or normal type of concept evolution." [10]

What, we should like to ask, is this "characteristic more or less common to all dogs and not common to cats, dolls, and 'teddy-

[9] *Ibid.*, p. 13.
[10] *Ibid.*, pp. 5, 6.

bears ' " that is the " ' meaning ' for the word dog "—a " characteristic " which for Hull obviously finds its counterpart in the " certain strokes in common " running throughout any one group of Chinese characters? What is the " common element " in " dog "? Is it something within the *visual* stimulus pattern? If exact drawings were made of all the dogs now living, or even of those with which any given child is familiar, would they " contain certain strokes in common " which could be " easily observed imbedded in each "? Or is the " common element " in " dog " something within the stimulus patterns of some other sense modality? Is it, for example, the sound of the barking of dogs—a thing " not common to cats, dolls, and 'teddy-bears ' "?

Let us approach the point at issue from another angle. In " Plate I.—Showing the Chinese characters which served as the material for the evolution of concepts " [11] Hull presents, among other things, two columns, one labeled " Word," the other " Concept." The former consists of " oo," " yer," " li," " ta," etc. The latter consists of the figures each of which constitutes the strokes which are common to all of the members of its group. Let us carry this over into Hull's illustration. Under " Word " we would obviously have " dog," " cat," " doll," " ' teddy-bear,' " etc. But what would come under " Concept "?

Moreover, both Hull and Gengerelli (whose study is intimately related to that of Hull) clearly indicate that the " common element " *is* the concept so far as they are concerned. " Concept " and " common element " are interchangeable. Thus Hull gives the label " Concept " to the column of figures each of which constitutes the strokes which are common to all the members of its group when he first presents these figures (on page 10). Later (on page 80) the very same column is labeled " Common element." Generelli also obviously regards the two phrases as synonymous. Thus, for example, he asks, " Would it, therefore, be more difficult for a group of S's to evolve the nine ' concepts ' or common elements contained in the material shown in Fig. 1,

[11] *Ibid.*, p. 10.

taken horizontally, after having evolved nine other ' concepts ' or common elements from the *same* material, taken vertically? " [12]

From the foregoing it may be seen, we believe, that Hull was investigating quantitative aspects of the process of finding " elements " common to each of a group of stimulus patterns and of overlooking portions of each pattern not common to other members of the group. Such a process can perhaps be called " abstraction," but it is hardly a matter of " evolution of concepts." [13] For elements are never evolved—they are merely analyzed out. As one learns more and more about dogs, his concept of "dog" becomes increasingly rich,[14] not a closer approximation to some bare " element." Moreover, as we have intimated, there is probably no " element " which can be approximated.

The " common element " in concept formation (in the sense employed by Hull and most other writers who use the phrase) is probably a pure fiction. We are not sure whether or not one could artificially set the stage in such a way as to evolve a concept after the manner of Hull and the " common element " doctrine. But certain it is, we believe, that such is *not* the " ' standard ' or normal type of concept evolution " with which Hull claims to be dealing. Life situations simply do not present " common elements " in stimulus patterns. No learner of " dog " ever found a " common element " running throughout the stimulus patterns through which he learned. The sheer fact of the matter is that the stimulus patterns which precede the formation of the concept " dog " do not contain a check mark, dot, cross, or anything corresponding thereto which is the " ' meaning ' for the word dog " and which may be regarded as an element common to them, but not common to stimulus patterns which precede the formation of other concepts.

We have dwelt at some length on this doctrine of the " common

[12] *Op. cit.*, p. 640.

[13] It is to be noted that this does not assert that the process of abstraction is never operative in concept formation.

[14] That is to say, the range of his behavior widens.

element" because it has gained wide acceptance and because it has been basic to practically all of the objective experimental work which has claimed to be in any way concerned with concept formation.[15] Investigators who have avoided introspection have followed Hull in basing their experiments upon the view that they were studying concept formation (or "inductive inference," as Kuo called the process which he investigated) when all the members of any one group of stimulus patterns which they presented had "certain strokes in common," that is, a "common element." Even a hasty glance at the stimulus figures which they used will show this to be the case. Moreover, Kuo explicitly defines "inductive inference" in terms of the doctrine of common elements. Thus, ". . . by inductive inference I mean merely a series of language reactions to different stimulus settings or different groups of stimulus patterns *when these latter have each an element in common,* and provided that this language series terminates in a new organization or regrouping of words ('conclusion,' statement of law, or principle), and provided that this new organization, in turn, is such as might become an abridged, economical, and general adjustment act of the organism in response to any stimulus setting in which the constant stimulus-factor may be present." [16] Of course, if Kuo does not mean by "inductive inference" what Hull means by "evolution of concepts," [17] or what is usually called "concept formation" or "generalization," the foregoing criticisms do not apply to him. Yet if Kuo uses the phrase "inductive inference" to refer *solely* to those processes that lead up to the formulation of such laws as the laws of thermodynamics, for example, we believe that the essentials of our critique of the elementarism of Hull and

[15] Miss Sullivan's monograph is a case in point. (Sullivan, Ellen B. Attitude in relation to learning. *Psychological Monographs,* Vol. 36, No. 3, 1927. Pp. 149.)

[16] *Op. cit.,* pp. 247, 248. (The italics are Kuo's.)

[17] Kuo does not clearly state just how "inductive inference" differs from "evolution of concepts," perhaps because Hull does not define *his* phrase. Kuo merely says, "While Hull is interested mainly in determining the relative efficiency of different methods for the evolution of 'concepts,' my own interest lies . . . in studying the various modes of language reaction involved in the process for which I have used the term inductive inference." (*Ibid.,* p. 249.)

Gengerelli would be applicable to him. If " inductive inference " refers to something other than the alternatives which we have suggested, we confess to a complete ignorance concerning it.

The question may fairly be raised whether there is not a sense in which the notion of a " common element " is sound. Is not color, for example, a " common element " in the case of certain concepts? The answer seems to us to be this: color may be called a " common element " if one wishes to use the phrase; but there is a danger in so doing. As the phrase has been used in the experimental literature it has referred not to a condition such as color but to a *term* within a stimulus pattern, a *section* of a pattern. This term, or section, has been called an " element," and concept formation has been made a mere matter of finding this " element." The learner has been made to resemble an enemy bomber in search of a camouflaged fortification or gun. Once the learner has separated the term from its camouflaging and been able to name the " element " when it has been presented to him, he has been regarded as having formed the concept. It is against this view of things that we have argued. Because the phrase " common element " has been associated with this view in psychological literature, we suggest that the use of the phrase be abandoned.

It seems doubtful to us whether one can any longer hold that the discovery of one or more " common elements " either constitutes, or results in, the formation of a concept unless there is at the same time a response to the relationships existing between these " elements " in the stimulus pattern.[18] Moreover, the " elements " in any stimulus pattern are such only in the sense that portions of that pattern may be singled out for purposes of convenience. Thus, as we look out of our window, the tall oak tree and the bed of flowers across the street are " elements " within our stimulus pattern, if one wishes to call them such. This, however, is merely a convenient fiction. For neither the tree nor

[18] Kuo recognizes " reaction to relationship " as one of the five " aspects " of " inductive inference." But his basic elementarism comes out clearly in his definition of " inductive inference " and in his use of " certain strokes in common " (Hull's phrase) in every stimulus figure belonging to a given group.

the bed of flowers is for us what it is apart from the grass, house, etc., that we see.

The abandonment of the "common element" doctrine means the substitution of a total pattern for a term within (*i.e.* a section of) a pattern as the proper material for the study of concept learning. The learner's task is no longer that of seeking for a hidden "element"; there is nothing that needs to be hidden or camouflaged. The total pattern, not some "element" in it, *is* a "wez" (or whatever other name is given to that type of object).

From our point of view the *sine qua non* of concept formation is a response to relationships common to two or more stimulus patterns. Perhaps some of our concepts ("beauty," for example) go back to stimulus patterns that have *only* relationships in common. Others ("American flag," for example) involve not only relationships but also color; and so on. In every case, however, there are relationships existing within groups of stimulus patterns that are dynamic wholes.[19]

By "concept formation," "generalization," or "concept learning" we refer to the process whereby an organism develops a symbolic response (usually, but not necessarily, linguistic) which is made to the members of a class of stimulus patterns but not to other stimuli.[20] Such a generalized symbolic response is not a "common element." Nor is it either identical with or adequately represented by "certain strokes" on a sheet of paper which are present in each member of a group of stimulus patterns.

At the present time no one can tell exactly what it means to have a concept in the biophysical sense.[21] That is to say, the neuromuscular and neuroglandular events that occur in the formation of any given concept are unknown. But it is possible to set up biosocial criteria which, though somewhat arbitrary, are socially

[19] By a "dynamic whole" we mean that any portion of the stimulus pattern that one singles out for consideration both influences and is influenced by the rest of the pattern.

[20] It may well be that, as Hull suggests (in Chapter 2 of his monograph), there are several more or less characteristic types of concept formation.

[21] We employ the terms "biophysical" and "biosocial" in the sense in which they have been presented and defined by A. P. Weiss. See, for example, his article on The biosocial standpoint in psychology, in *Psychologies of 1930*.

and statistically justifiable. In this study, for example, we count the subject as having learned a concept if he is able to go faultlessly through a test series of sixteen stimulus patterns, some of which fulfill the conditions of the concept in question and some of which do not. Let us suppose that the concept is "zum" and may be defined thus: "three straight red lines, two of which intersect the third, thereby trisecting it." When the subject has indicated his belief that he knows what a "zum" is, he is asked to go through a series of sixteen drawings (stimulus patterns), some of which are "zums" [22] and some of which are not,[23] writing "Yes" after the number of each drawing that is a "zum," "No" after the number of each drawing that is not a "zum." If no mistakes are made, we regard the subject as having learned the concept in question.

The foregoing account seems to us to be devoid of both the mysticism that often accompanies a discussion of concepts and the oversimplification of the doctrine of the "common element."

If the point of view and criticisms advanced in this chapter are sound, one is led to wonder whether there has ever been an adequate natural-science attack upon concept formation.[24] Whether or not our work constitutes such an attack we do not claim to know, for only time can tell. We offer it as an attempt in that direction.

[22] In order to be true to ordinary learning situations, these drawings were made to vary in size, position, width of line, etc.

[23] In order to make the test a crucial one, each of these latter drawings violated the conditions in only one respect, and all the conditions likely to be overlooked were violated in at least one figure.

[24] This in spite of the fact that, as B. H. Bode points out, "There is a sense in which we can say that the whole of education centers on the development of concepts." (*Conflicting Psychologies of Learning*, p. 265.) Is it not strange that so much time and money have been spent on "educational research" that has dealt with almost everything under the sun except the problems of this fundamental and all-important process?

CHAPTER II

Apparatus and General Method

Figure 1 shows the exposure apparatus used throughout the experiments reported in subsequent chapters. Figure 2 is a schematic diagram of the electrical systems involved.

Six volts of direct current from a storage battery energize the coil of a double pole contactor (O) [1] at certain intervals of time. The circuit is completed, and the coil of the contactor is therefore energized, when a roller (F) [2] comes in contact with a metallic spool (H) by virtue of an opening in the motion-picture film (L) [3] that separates them. This film travels at the rate of one inch per second, and the openings in it are approximately one-half inch in length. The exact length of the openings, so long as it is less than one inch, is not a matter of importance, however, for a pin (E) in a cam that rotates (and steps the drum) in one second breaks the circuit at a breaker contact (D) only after the cam has completed its revolution. Thus the circuit is "made" (and the contactor closed) at the instant the roller drops through an opening in the film and touches the metallic spool; and the circuit is broken (and the contactor opened) one second later when the cam has completed one revolution. As the steel plate at the side of the drum has one pin (K) for each of the sixteen faces of the drum, the net result of one cycle of the timing driver is that the drum is stepped ahead one position (*i.e.* moved one-sixteenth of a revolution). The drum is held solidly in this position because the cam, which is heart-shaped, is wedged between adjacent pins.

[1] This letter and all others subsequently used in describing apparatus refer to Figure 1.

[2] In point of fact two rollers were used in order to assure perfect contact. They were of course connected in parallel, and the holes in the film were punched in pairs to correspond with them.

[3] The emulsion had been removed from the film by soaking it in hot water.

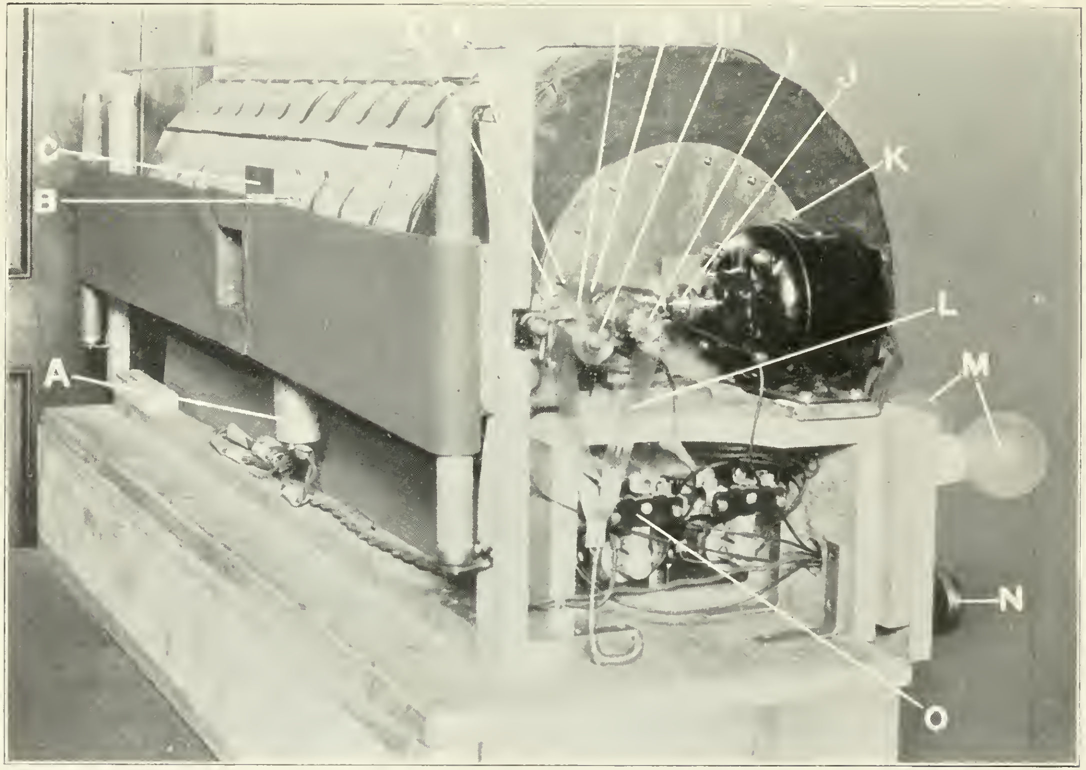

Fig. 1
Exposure Apparatus

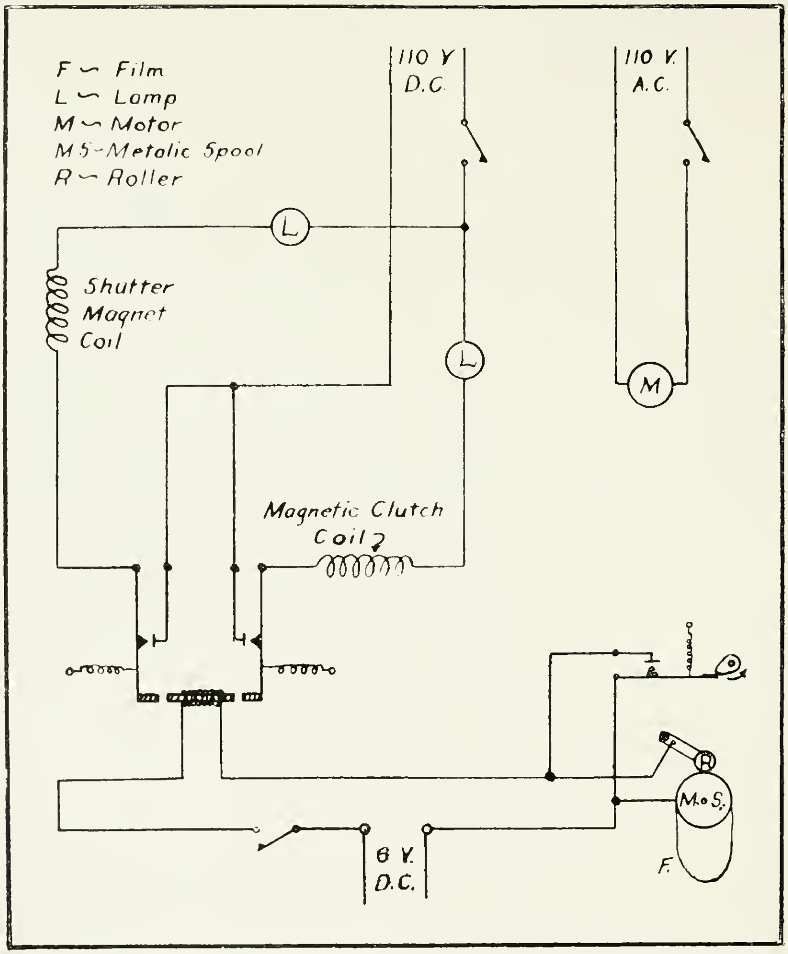

Fig. 2
Schematic Wiring Diagram

The closing of the contactor completes two circuits of 110 volts of direct current. One of these energizes a magnetic clutch (G) coil on a clutch shaft. (A lamp [M] serves as resistance.) The instant the contactor is closed the clutch shaft engages the cam shaft. The other circuit, again with a lamp as resistance, energizes the solenoid (A) of the shutter. The plunger of this solenoid operates a system of levers that moves an upper shutter plate of black wood fiber (C) and a lower one in a vertical plane. This shutter operates behind a window two and one-half inches square, the shutter plates meeting on a horizontal line bisecting the opening. The window is therefore opened from the middle.

A one-hundredth horse power synchronous motor (G.E., type SKS, 60 cycles, 1800 r.p.m.) moves the drum. It is connected by means of a coupling (J) with a worm unit giving a reduction of thirty to one between the motor and the clutch shaft. The speed of the motor being 1800 r.p.m., the clutch shaft therefore rotates once per second. Spur gears effect a further reduction of three to one between this shaft and the film sprocket (I). The film sprocket is three inches in circumference.

Three toggle switches (N) control these circuits. Together with the two electric light bulbs (M) and two binding posts, they are mounted on a panel.

The shutter unit may be moved back and forth on two steel shafts. A pin (B) on it drops into notches filed at critical points in the upper shaft. Thus the shutter unit is held in position for the exposure of any given series of cards.

The mechanism is completely screened from the view of the subject by a framework on which black oil cloth has been stretched. An opening three and one-half inches high and thirty-nine inches long extends most of the distance across the front of this screening on a level with the window of the shutter unit (and with the subject's eyes). Mounted six inches above this opening there is a black window shade forty-two inches in length, which may be pulled down whenever the subject is not examining the cards on the drum. Behind the opening a strip of black window shade five and one-half inches from top to bottom, in which a

hole three and one-quarter inches square has been cut to correspond with the window, is joined to the shutter unit and travels back and forth on upright rollers as the shutter unit is moved.

The sequence looking from the position of the subject towards the exposed card on the drum is as follows: (1) opening in screen framework; (2) vestibule three and one-quarter inches square leading into the window frame behind which the shutter moves; (3) hole two inches square in a piece of black wood fiber that is mounted on the shutter unit but as near to the drum as possible.

Everything is therefore screened from the view of the subject except an area of the exposed card two inches square.

Any exposure apparatus has both defects and points of merit. This one can be criticized as being somewhat bulky and noisy.[4] It does possess, however, a number of very desirable features. For example, space on the drum is provided for twelve series of sixteen cards[5] each (each card is three inches square), thus making it unnecessary in most experiments to touch the cards for weeks at a time. Again, any exposure time whatsoever is possible by the simple expedient of punching holes at the proper intervals in a piece of film and then cementing the ends of the film. Again, the exposure time can be put completely under the control of the subject (or of the experimenter) by simply placing a piece of unpunched film (or other insulator) between the roller and the metallic spool and then substituting a contact key for the roller-spool contact. Moreover, by a change in the wiring and the introduction of the second contactor, any interval between exposures is possible. Any conceivable combination of exposure time and interval between exposures is then available.

As there were no windows in the experimental room, all of the illumination came from two 100-watt electric light bulbs. One of these illuminated the room in general. The other, a daylight bulb, was in a desk lamp, which was readjusted each time

[4] The noise, of course, comes from the shutter and the contactor.

[5] Spring brass clips hold the cards in position.

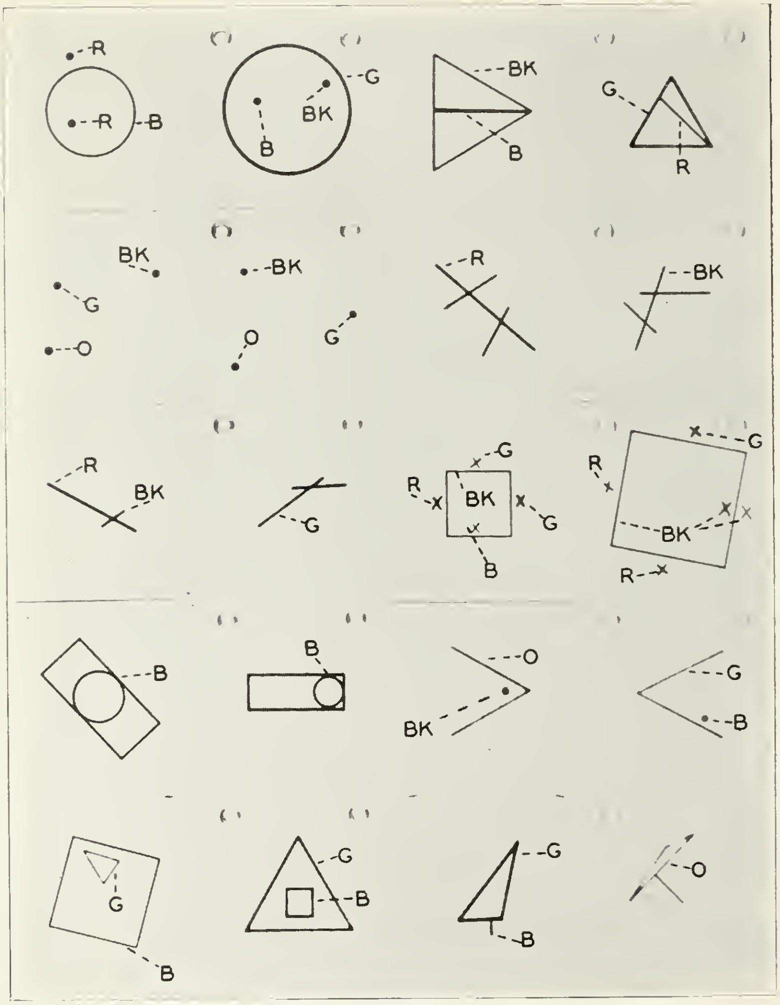

Fig. 3
Specimens of Designs Used in the Experiments

the window was moved, so that the light fell directly upon the surface of the exposed card.

Ten concepts were used in this study. Each concept concerned a certain type of geometrical design. Each type of design was given a name, the names selected being these: "dax," "vec," "zif," "zum," "mef," "tov," "pog," "wez," "gid," and "mib."[6] A specimen of each type of design is shown in Figure 3. Columns one and three, reading from left to right, contain these specimens. The letters refer to colors: "O" stands for orange, "R" for red, "G" for green, "B" for blue, and "BK" for black. Each design in these two columns is a "regular" figure; that is to say, it fulfills all of the conditions essential to the concept in question. To the right of each "regular" figure is a "confusion" figure; that is, a design that violates at least one of the conditions essential to the concept in question. Thus, in the upper left-hand corner there is a "regular" figure of "dax," *i.e.* a drawing that fulfills all of the conditions essential to the concept "dax." To the right of this drawing is a "confusion" figure of "dax," *i.e.* a drawing that violates at least one of the conditions essential to the concept "dax." Each confusion figure in Figure 3 violates only one condition essential to the concept in question. A definition of each of the ten concepts follows:

A "dax" is a circle and two dots, the one dot being inside the circle and the other outside of it.

A "vec" is an equilateral triangle together with a line which is perpendicular to one side and which extends from that side to the vertex of the opposite angle.

A "zif" is three dots, the distance between the two farthest dots being twice the distance between the two nearest ones.

A "zum" is three straight red lines, two of which intersect the third, thereby trisecting it.

[6] These nonsense syllables were chosen from the lists given by Glaze. (Glaze, J. Arthur. The association value of non-sense syllables. *Pedagogical Seminary and Journal of Genetic Psychology*, 1928, **35**, 255–269.) Glaze found that none of his fifteen subjects had associations for "dax," "mef," "tov," "vec," "zif," and "zum," and that only one subject had associations for each of the others listed above. The syllables were pronounced as follows in the present study: "dax," "vec," "zif," "zoom," "mef," "tōv," "pōg," "wez," "gid," and "mib."

A " mef " is two intersecting straight lines, the length of the shorter being equal to the distance from it to the nearer end of the longer line.

A " tov " is a square and four crosses, each side of the square having a cross that is nearer to it than to any other side.

A " pog " is a blue rectangle enclosing a blue circle that touches only the long sides of the rectangle.

A " wez " is two straight lines of equal length that touch on end together with a dot equidistant from the free ends of the lines.

A " gid " is a green triangle and a blue square, the triangle being within the square but not touching it.

A " mib " is a triangle and a line extending at right angles from its shortest side.

All figures used in both learning and testing were drawn on three-ply gray Duro Bristol cards three inches square in Higgins' orange, brick red, green, blue, and india ink.[7]

The regular figures used in learning were drawn so as to differ greatly among themselves, though still being true representations of the concept. For example, the regular figures employed in the series for " dax " differed from one another as regards size and color of the circle, width of line of the circle, color of the dots, and position of the dot inside the circle and of the dot outside of it. But they always consisted of a circle and two dots, one dot being inside the circle and one outside of it.

In three of the four experiments here reported confusion figures were used along with the regular ones in learning. As was the case with the regular figures, these were made unlike each other in size, color, position, width of line, etc.

The instructions and procedure varied somewhat from experiment to experiment, but the general methodology was the same throughout.

On entering the experimental room, the subject was invited to take a seat at a table on the other side of which (at a distance of one and one-half to two feet from the subject's eyes) the ex-

[7] If a subject exhibited the slightest sign of color-blindness, he was excused from the experiment, and his results were discarded.

posure apparatus rested. The window shade having been pulled below the level of the window of the apparatus, the subject saw no portion of the apparatus except its screening.

When the subject indicated that he understood the instructions, the experimenter raised the window shade (thus making it possible for the subject to see the learning designs) and at the same time started a stop watch. When the subject raised his hand (thereby indicating that he thought he had learned the concept), the experimenter lowered the shade, stopped the stop watch, and recorded the time on a time card.[8] The time spent by the subject in examining the designs (*i.e.* the number of seconds the window shade was raised) was taken as the best available measure of the difficulty of the concept and of the speed with which the subject learned it.

The experimenter then handed the subject a sheet of paper and a pencil, and said, " I shall give you three tests. The first of these is that of definition. Please state what a '—— ' is " After the subject had finished, the experimenter gave him another sheet of paper, saying, " The second test is a matter of drawing. Please draw two '——s.' " In introducing the third test the experimenter handed the subject a sheet of paper on which columns of numbers from one to sixteen had been mimeographed and a standard office calendar file containing test cards, and said, " Here is a series of sixteen drawings. Some of these drawings are '——s ' and some of them are not. If the drawing is a '—— ' write ' Yes ' after its number. If it is not a '—— ' write ' No.' If you should happen to change your mind as to what a '—— ' is, be sure to stop and change your definition." If the subject made no mistakes in going through the test series, he was regarded as having formed the concept. The experimenter then moved the shutter unit over to the series of designs on the drum from which the next concept was to be learned. If the subject made mistakes, the experimenter said, " You know something about '——,' but you do not know everything. We shall try it again."

[8] In experiments I and II the experimenter also took and recorded the time consumed by the subject in taking the tests which were given to him.

Because the discriminative responses involved in going through the test series were regarded as the crucial test of whether or not the subject had learned the concept, the construction of the test series was a matter of considerable importance. Such a series was developed for each of the ten concepts, a series consisting of sixteen figures, each drawn on a card that had been eyeleted so as to fit a standard office calendar file. About half of these sixteen figures were regular figures; the others were confusion figures. These two types of figures were mixed in "chance" order, and each card was numbered and placed in its position in the calendar file. The regular figures, like those used in learning, were drawn so as to differ greatly among themselves, though still being true representations of the concept. The confusion figures, like those used in learning in experiments II, III, and IV, were also made unlike each other. Moreover, they were drawn according to two principles: (1) each confusion figure must violate one and only one condition essential to the concept; (2) every condition essential to the concept must be violated at least once.[9] A glance at the responses made by the subject while going through the test series was therefore all that was needed to discover what he had failed to learn, if anything.

Clearly there is here no effort to deal with "common elements." Certain things are in common among the regular figures, as they of course must be if the objects are to form a class and if the learner is to form a concept. A "mib," for instance, always involves, among other things, a line touching a triangle. But neither this nor any other aspect of a "mib" is a "common element" in the sense of a portion of a stimulus pattern that is practically invariable among all the members of its class and that *is* the concept "mib." For "mibs" are like "dogs" and most other things in being much too different from one another for anything so simple as that.

[9] It was not deemed necessary or desirable always to adhere to this rule rigorously. In drawing the confusion figures for the "zum" test series, for example, the lines were never made to zig-zag or curve.

CHAPTER III

Experiment I

This was a preliminary experiment, the purposes of which were (1) to test the value of ten geometrical designs as stimulus patterns for concept formation, and (2) to gain some notion of the relative difficulty of the ten concepts.

Preliminary trials with six or seven subjects had shown that three seconds was a desirable exposure time for the type of designs here used. This exposure time was accomplished by means of a piece of motion-picture film that had been punched, and its ends cemented, in such a way that the beginnings of adjacent pairs of holes were four inches apart. As the film moved at the rate of one inch per second, four inches of film represented an interval of four seconds between any instant when the primary circuit was completed and the next instant this circuit was completed. During one of these seconds the window shutter was closed and the drum was being stepped ahead. During the other three seconds the shutter was open and the drum and the exposed card were stationary. The apparatus ran constantly from the time the subject entered the room in order that he might become adapted to the sound of the shutter and the contactor.

Ten rows or series of cards were placed on the drum. Each series consisted of sixteen cards, and each card contained a regular figure of one of the concepts mentioned in Chapter II. Each of the ten series consisted of designs of one of the ten concepts.

The subjects, twenty in number, were recruited from the students taking the introductory course in psychology. They were instructed somewhat as follows ("dax" being used as an example):

"You will see a series of figures (or drawings) each and every one of which is called a 'dax'— D A X, 'dax.' Try to find out everything a figure must be if it is to be called a 'dax.' I shall illustrate what I mean.

"You will recall that until recent years there were no 'chairs' in Japan. Even today there are residents of parts of Japan who have never seen what we call a 'chair.' Let us imagine one of these people coming to America. He has

to learn, along with many other things, what a 'chair' is. You are in much the same situation, except that instead of learning what a 'chair' is you will learn what a 'dax' is. When you think you know what a 'dax' is, raise your hand."

The order of presentation of the ten series was scattered in the following way: Subject A learned the concepts in the order in which they are presented in Table 1, reading from left to right; subject B started with "vec," then learned "zif," "zum," and so on, learning "dax" last; subject C started with "zif" and learned "vec" last; and so on through subject J. Subject K learned the concepts in the order in which they occur in Table 1, reading from right to left; subject L started with "gid," then learned "wez," "pog," and so on, learning "mib" last; and so on for the rest of the subjects.

If the subject had not learned the concept after a total of ten minutes had been spent in examining the designs and in taking the tests, the experimenter defined the concept for him, and turned to the next series. The experimental period never lasted more than fifty minutes. If the subject did not have time to deal with all ten concepts during the first two periods, he was asked to return for a third period.

"Zif" and "mef" proved to be unsuited to experimentation of this type because of the presence of illusory effects. The tendency which many individuals have of over-estimating vertical distances as compared with horizontal distances was the important factor here, for both "zif" and "mef" involve the judgment of the relative length of two distances that lie in different planes relative to vertical and horizontal. The apparent relative length of the two distances varied from subject to subject, invalidating the results. There were no indications that any of the concepts other than "zif" and "mef" were unsuitable for experiments on concept formation.

Table 1 shows the time in seconds spent by each subject in examining the designs.[1] Table 2 shows the total time, in seconds, spent by each subject in examining the designs and in taking the tests.

[1] No allowance is made in this or any subsequent table for the interval of one second that always separated successive exposures.

TABLE 1

Showing the number of seconds spent in examining the designs, Experiment I

Subject	Dax	Vec	Zif	Zum	Mef	Tov	Pog	Wez	Gid	Mib
A	203	37	x	x	x	79	x	85*	190	85
B	37	18	x	183*	x	54	38*	33	69	28
C	84	46	x	x	83	75	76	55*	83*	75
D	86	36	x	x	x	x	66*	101	53	x
E	126	118	x	x	x	x	140*	111	132	154
F	80	75	x	x	66	x	x	76	96	61
G	23	19	65*	444	127*	46	x	46*	29	46
H	39	16	x	x	x	92	28	x	x	60*
I	64	23	x	x	x	76	78	87	158	x
J	45	24	x	x	145	102	59	64*	101	x
K	45	42	142*	81	x	97	48	68	x	x
L	113	113	x	x	x	x	178	x	x	x
M	52	32	x	x	x	156	137	56	28	244
N	44	21	x	x	x	67	x	22	21	44*
O	42	44	311	x	x	98	69	68	122	61*
P	133	212	x	x	x	305	65*	132	146	149
Q	87	114	x	x	178	x	71*	80*	125	x
R	x	46	x	x	x	84	x	115	x	136
S	15	31	102	52	x	116	33	34	x	101
T	43	66	x	232*	x	131*	32*	144	x	x
Midscore	58	40	x	x	x	100	74	78	128	142

* Subject learned something from the test series.

TABLE 2

Showing the total number of seconds spent in examining the designs and in taking the tests, Experiment I

Subject	Dax	Vec	Zif	Zum	Mef	Tov	Pog	Wez	Gid	Mib
A	431	157	x	x	x	335	x	335	398	201
B	99	150	x	414	x	243	134	126	141	99
C	194	159	x	x	207	210	250	197	414	196
D	165	110	x	x	x	x	239	259	147	x
E	306	347	x	x	x	x	503	284	452	454
F	339	407	x	x	336	x	x	373	262	312
G	116	122	339	600	344	147	x	177	118	256
H	165	137	x	x	x	375	137	x	x	364
I	325	176	x	x	x	203	303	280	540	x
J	178	172	x	x	441	215	168	244	227	x
K	148	180	510	245	x	294	183	340	x	x
L	194	215	x	x	x	x	442	x	x	x
M	138	132	x	x	x	446	389	289	135	479
N	155	183	x	x	x	289	x	171	218	192
O	171	173	531	x	x	339	172	244	229	269
P	231	351	x	x	x	516	184	276	253	309
Q	281	306	x	x	370	x	268	276	265	x
R	x	431	x	x	x	241	x	314	x	367
S	133	220	340	240	x	495	138	157	x	504
T	214	294	x	536	x	527	231	495	x	x
Midscore	186	178	x	x	x	357	259	278	332	410

An examination of Table I will indicate that there were very great individual differences (1) in the relative difficulty of the

ten concepts for the various subjects and (2) in the degree to which the various subjects found any one concept to be difficult. In many instances the subject did not learn the concept in the time allowed for learning in this experiment. The symbol " x " is used in this and subsequent tables to refer to these instances in which the subject failed to learn the concept within the limits which the experimenter set for the experiment in question. The large number of these unknown quantities in Table 1 make it virtually impossible to deal with the results statistically except in terms of midscores. None the less, subsequent experimentation showed that these midscores are reliable indicators of the relative difficulty of the concepts, difficulty being measured in terms of the time spent in learning. Leaving " zif " and " mef " aside, " vec " and " dax " are probably the easiest, and " mib " and " zum " the most difficult. " Pog " and " wez " are probably of intermediate difficulty. (" Gid " and " tov " were used in subsequent experimentation, but only as illustrations.)

Subjects who went through the test series faultlessly almost invariably made drawings that were precise representations of the concept, within the limits of accuracy in free-hand drawing, but their definitions were often defective. Of the 128 definitions that accompanied a perfect performance on the test series, thirty-nine were defective. In other words, it frequently happened that the subjects, though able to discriminate with accuracy and consistency, could not give an acceptable verbal formulation of what they had learned. This happened again and again in subsequent experiments. The defective definitions both in this and in the other experiments were usually too inclusive.

Summary of Results

(1) All of the concepts defined and illustrated in Chapter II are suitable for studies of concept formation except " zif " and " mef."

(2) " Vec " and " dax " are probably the easiest, " mib " and " zum " the most difficult, of the eight remaining concepts.

(3) Individuals who have learned concepts may be unable to give an accurate verbal formulation of them.

CHAPTER IV

Experiment II

The purpose of this experiment was that of comparing the rapidity of concept learning from series consisting of (1) positive instances only and (2) both positive and negative instances.

In Experiment I the subject had no control of the exposure apparatus—each design appeared for three seconds, and then the shutter closed. In this experiment the exposure apparatus was put under the control of the subject by substituting a contact key for the roller-spool contact and by placing this key on the table within easy reach of the subject. He pressed this key if and when he wished to see another design. Two series each (of sixteen cards each) of "vec," "dax," "pog," "wez," "mib," and "zum" were placed on the drum. For each concept one of the series consisted of only positive instances, *i.e.* regular figures, of the concept in question. The other series consisted of eight positive instances and eight negative instances, *i.e.* confusion figures, arranged alternately. A plus sign was drawn in india ink under each positive instance, a minus sign under each negative instance. The negative instances were much like those in the test series, for they fulfilled all but one of the conditions essential to the concept, and every condition essential to the concept was violated in at least one figure.

The subject was given a preliminary period of training in the form of the following two illustrations in order that he might become familiar with the procedure. The experimenter, handing the subject a pack of sixteen cards, said, "I am going to show you how we shall proceed when we come to the experiment proper. Here are some drawings each and every one of which is a 'tov.' Try to find out everything that a drawing must be if it is to be called 'tov.' Or in other words, try to find out what

a ' tov ' is. When you think you know, raise your hand." When the subject raised his hand, he was given the three tests (as described in Chapter II). If he had not learned " tov," the experimenter defined it for him.

Then the experimenter handed the subject another pack of sixteen cards, and said, " Here are some more drawings. Some of these are ' gids ' and some are not. If the drawing is a ' gid,' there is a plus sign under it. If the drawing is not a ' gid,' there is a minus sign under it. As before, try to find out everything a figure must be if it is to be called ' gid.' Or in other words, try to find out what a ' gid ' is. When you think you know, raise your hand." When the subject raised his hand, he was given the three tests. If he had not learned " gid," the experimenter defined it for him.

He was then told that this was the procedure that would be followed in the experiment, except that the cards would be seen through a window in the apparatus and that when he wished to see another card, he was to press the contact key.

Each time the subject was ready to start on a new concept the experimenter said, " Each and every one of these drawings is a ' —— ' " (if the series contained only positive instances) or " Some of these drawings are ' ——s ' and some of them are not " (if the series contained both positive and negative instances).

Twenty-four undergraduates were used as subjects in this experiment. Each subject came for two experimental periods, learning two concepts the first period and four the second.

The order of presentation of the concepts was scattered as in Experiment I, each subject dealing alternately with the two types of series. Thus, subject A learned " vec " from the " vec " series containing only positive instances, " dax " from the " dax " series containing both positive and negative instances, " pog " from the " pog " series containing only positive instances, and so forth; subject B learned " vec " from the " vec " series containing positive and negative instances, " dax " from the " dax " series containing only positive instances, and so forth; subject C

learned "dax" from the "dax" series containing only positive instances, "pog" from the "pog" series containing both positive and negative instances, and so forth, learning "vec" last; and so on, up to and including subject L. Subjects M to X learned the concepts in the reverse order. Subject M learned "zum" from the "zum" series containing only positive instances, "mib" from the "mib" series containing both positive and negative instances, and so forth; subject N learned "zum" from the "zum" series containing both positive and negative instances, "mib" from the "mib" series containing only positive instances, and so forth; and so on for the rest of the subjects.

Table 3 shows the time in seconds spent by each subject in examining the designs. Table 4 shows the total time in seconds spent by each subject in examining the designs and in taking the tests.

As in Experiment I, the number of unknown quantities precludes the possibility of extensive statistical treatment of the results. It is clear, however, that there is here no reason for holding that either of the two types of learning series is more instructive than the other. This result came as a surprise to the experimenter, as he had expected that the series containing both positive and negative instances would prove to be more instructive than the series containing only positive instances. In those cases in which the critical ratio can be computed (*i.e.* in "vec" and "dax") the differences between the means are insignificant. The series containing only positive instances has somewhat of an advantage in the case of "pog" and "mib," as a glance at the midscores in Table 3 shows. This advantage is offset, however, by the fact that in both "pog" and "mib" the subjects learned from the test series more frequently in the case of the series containing only positive instances than in the case of the series containing both positive and negative instances.

Some subjects seemed to find the negative instances instructive, or at any rate they spent quite a little time with them. Other subjects looked at the negative instances for only a moment, apparently learning little or nothing from them. One subject,

TABLE 3

Showing the number of seconds spent in examining the designs, Experiment II

Subject	Vec (P)	Dax (P, N)	Pog (P)	Wez (P, N)	Mib (P)	Zum (P, N)
A	25	20	x	79*	24	x
D	211	318	85	184*	x	x
E	29	28	x	68	84	x
H	63	55	x	78	193	x
I	46	60	25*	74*	39*	x
L	23	24	76*	66	135	164
N	25	20	41*	39	64*	x
O	36	23	49	74	52*	x
R	20	30	40	98	55*	x
S	27	39	46*	84	266*	x
V	14*	26	39*	60	85	x
W	28	55	42	157	x	x
Midscore	28	29	48	76	84	x

Subject	Vec (P, N)	Dax (P)	Pog (P, N)	Wez (P)	Mib (P, N)	Zum (P)
B	36	14	38	40	103	x
C	90	76	x	x	x	x
F	40	61	100	27*	66*	x
G	50	45	50	119*	358	x
J	60	49	60	161	140	x
K	32	33	16	27*	x	x
M	61	182	93	x	x	x
P	26	42	76	75*	90*	x
Q	45	39	76	39	55	x
T	75	60	50	78	227	x
U	26	33	56	27	x	x
X	36	187	66	121	168	x
	42	47	63	76	198	x

* Subject learned something from the test series.
(P): Series consisted of only positive instances.
(P, N): Series consisted of both positive and negative instances.

TABLE 4

Showing the total number of seconds spent in examining the designs and in taking the tests, Experiment II

Subject	Vec (P)	Dax (P, N)	Pog (P)	Wez (P, N)	Mib (P)	Zum (P, N)	Subject	Vec (P, N)	Dax (P)	Pog (P, N)	Wez (P)	Mib (P, N)	Zum (P)
A	143	117	x	230	124	x	B	159	138	274	388	510	x
D	485	519	276	492	x	x	C	257	230	x	x	x	x
E	189	145	x	295	355	x	F	130	143	270	123	260	x
H	187	161	x	215	473	x	G	180	158	193	320	587	x
I	307	236	185	359	259	x	J	230	191	203	474	358	x
L	123	142	405	294	502	299	K	204	106	114	116	x	x
N	124	121	240	164	187	x	M	264	307	267	x	x	x
O	163	144	266	342	427	x	P	140	213	336	308	253	x
R	299	233	408	362	237	x	Q	170	158	295	163	178	x
S	154	186	477	208	526	x	T	368	200	240	310	557	x
V	178	194	331	260	247	x	U	182	150	223	186	x	x
W	184	210	190	446	x	x	X	191	298	179	324	458	x
Midscore	181	174	368	294	391	x		186	174	254	315	534	x

(P): Series consisted of only positive instances.
(P, N): Series consisted of both positive and negative instances.

without having received the slightest suggestion from the experimenter, even went so far as to say, "The designs with the minus signs keep me from doing my own thinking." Frequently a subject would examine one negative instance with care but spend only a moment with some other one.

As in the previous experiment, there were a number of cases in which a subject who was able to make the correct discriminations on the test series could not define accurately. This occurred thirty-four times out of 109.

Summary of Results

(1) Some subjects appear to learn little or nothing from negative instances, and may even find them hindrances to concept learning. Others seem to find negative instances instructive. Perhaps most subjects learn something from some negative instances, but little or nothing from others.

(2) This experiment furnishes no statistically significant evidence to the effect that concept learning proceeds either more or less rapidly when the series contains both positive and negative instances than when it contains only positive instances.

(3) As in Experiment I, a considerable number of subjects wrote defective definitions after having gone through the test series without error.

CHAPTER V

Experiment III

This experiment was designed to furnish preliminary answers to these two questions: (1) Does concept formation proceed more or less rapidly when the negative instances violate the conditions essential to the concept in several respects than when they violate only one essential condition? (2) What can be said as to the nature of the process of concept formation?

The exposure apparatus was put under the control of the subject by way of a contact key (as in the previous experiment). The electromagnet controlling one pen of a Renshaw polygraph was wired into the apparatus in such a way that a record was obtained on the moving paper of the polygraph each time the key was depressed.[1] A second electromagnet controlling another pen of the polygraph was wired in with a seconds interval timer. The remainder of the space on the polygraph paper was used in recording what the subject said.[2] Thus a permanent record was obtained of the number of figures in each series examined by each subject, the number of seconds devoted to each figure, and the comments with reference to each figure.

Ten series of figures were used, one each of "wez" and "gid" and two each of "vec,", "dax," "mib," and "zum."[3] Approximately three-fourths of the figures in each series were instances of the concept in question; the remainder were negative

[1] This was simply a matter of placing both of the 110-volt D.C. circuits under the control of one pole of the contactor, and then running one wire from the electromagnet of the polygraph to the other pole of the contactor and the other wire to the battery.

[2] In this experiment the subject was asked to "do all" his "thinking out loud." It is not to be supposed, however, that any subject actually mentioned more than a fraction of what was "going through his mind."

[3] It will be recalled that "vec" and "dax" were the two easiest, "mib" and "zum" the two most difficult, of those concepts employed in Experiment I which proved to be useful in work of this type.

instances. Thus, for example, a distinct majority of the figures in the "wez" series were "wezs," but a few of them were not.

"Wez" and "gid" were used solely for the purpose of familiarizing the subject with the technique employed. The negative instances in the "wez" series fulfilled all of the requirements of "wez" except one. The negative instances in the "gid" series, on the other hand, violated at least two of the conditions essential to "gid." The cards of each series having been shuffled and then numbered,[4] they were placed on the drum in consecutive order from 1 to 16.

The two series employed in the case of "vec" were alike except for the negative instances. The negative instances in the one series violated only one condition essential to "vec" (*cf.* the "wez" series), whereas those in the other series violated two or more of these conditions (*cf.* the "gid" series). The cards constituting one series were shuffled and then numbered (from 1 to 16). The positive instances in the other series were then numbered as were their fellow figures, whereas the negative instances, having been shuffled, were inserted in the vacant places in the series and numbered correspondingly. Both series were placed on the drum in consecutive order from 1 to 16.

The series dealing with "dax," "mib," and "zum" were constructed and handled in the same fashion as those dealing with "vec."

Twenty-four undergraduates and two graduate students in psychology served as subjects in this experiment. Each subject came for two experimental periods. The following instructions were handed to him in typewritten form at the beginning of each period:

"You will see a series of geometrical designs or drawings. There are sixteen drawings in this series, and each drawing has its number under it. You will see them in order from one to sixteen. Each time you press the contact key (in front of you on the table) the next drawing in the series will appear.

"The apparatus operates in such a way that the series repeats itself indefinitely. Thus, drawing number 16 is followed by drawing number 1.

"*Most* of the sixteen drawings are members of one and the same class (or group), but a few of them do not belong to this class (or group). If a drawing *is* a member of this class (or group), it is a 'wez.' Otherwise it *is not*

[4] All cards used in this experiment were numbered in india ink immediately under their respective figures.

a 'wez.' *Your task is that of discovering the characteristics of this class (or group).* Or, in other words, *try to find out what a 'wez' is.*

"*When you think that you know what a 'wez' is, raise your hand.*

"It is very important that you *do all of your thinking out loud in this experiment.* Imagine you are all alone and simply talking aloud to yourself.

"The experimenter will record the time that you take, but do not hurry. Take as much time as you need. Yet do not dally or hesitate overlong.

"After you have learned 'wez,' you will learn 'gid,' 'vec,' 'dax,' 'mib,' and 'zum' (in this order) in the same way.

"Please reread the above instructions until you are absolutely sure that you understand everything. If you do not see what is meant by any point ask the experimenter about it."

Given the materials and the instructions used in this experiment, several concepts were possible. Thus, "zum" might be defined as "three straight red lines, two of which intersect the third." But when the subjects made "errors" in going through the test series, the usual instructions (*i.e.* "You know someting about '——,' but you do not know everything. We shall try it again.") forced him to another, and narrower, classification. Whatever else a concept may be, it is certainly an instrument for classification.

Half of the subjects (A to M in Table 5) learned "vec" from the "vec" series containing confusion figures that violated only one condition essential to "vec"; the other half (N to Z in Table 5) learned "vec" from the "vec" series containing confusion figures that violated two or more conditions essential to "vec." Subjects A to M later learned "dax" from the "dax" series containing confusion figures that violated two or more conditions essential to "dax"; subjects N to Z learned "dax" from the other "dax" series. And so on, each subject dealing alternately with the two types of series.

"Wez," "gid," and "vec" were learned the first experimental period, "dax," "mib," and "zum" the second. The subject was given only one trial (not to exceed five minutes) in the case of "wez" and "gid." In the case of the other concepts, the subject was allowed three trials, provided that not more than seven minutes were spent in examining the figures.

The subject was informed that "wez" and "gid" were "merely illustrations."

We came to the experiment supposing that concept formation ought to proceed more rapidly in cases in which the negative

instances depart rather widely from the concept than in cases in which the negative instances violate only one condition essential to the concept. In the former, we reasoned, the negative instances ought to accentuate the positive ones by contrast, and therefore make for speed in learning. As only twenty-six subjects were used in this experiment, one is not justified in making any sweeping generalizations.[5] At any rate the evidence at hand is against the above supposition—or at least fails to support it. Perhaps negative instances that violate only one condition essential to the concept force the subject to a more careful examination of the whole situation than do those that violate a number of essential conditions. This, however, is hardly more than speculation.

The use of Fisher's "t" function[6] supports the conclusion one tends to draw from an examination of Table 5, namely that there is here no evidence that concept formation proceeds more rapidly under the one set of conditions than under the other.

The problem of the nature of concept formation is so complex that only prolonged experimentation involving many lines of attack can yield anything approaching a solution of it. We believe, however, that the technique employed in this experiment has justified itself in the results obtained.

Our results seem to point clearly to the presence of grouping in the process of concept formation. The same sort of organization into groups which Bryan and Harter found in their study of the process of learning to send and receive telegraphic messages[7] appears to be operative in the formation of concepts.

[5] Assuming the presence of negative instances, there may, for example, be an optimum number of them and an optimum degree to which they violate the conditions of the concept in question. Again, successive presentation may yield results very different from those of simultaneous presentation in matters of this sort. Of such things we know, so far as the writer has been able to discover, absolutely nothing.

[6] This is perhaps the most valuable statistical instrument for use with small samples that is now available. See Fisher, R. A., *Statistical Methods for Research Workers*, especially Chapter 5.

[7] Bryan, W. L., and Harter, Noble. Studies in the physiology and psychology of the telegraphic language. *Psychological Review*, 1897, **4**, 27–53, and Studies in the telegraphic language. The acquisition of a hierarchy of habits. *Psychological Review*, 1899, **6**, 345–375.

Twenty-four undergraduate students and two graduate students in psychology served as subjects in this experiment. Twenty-three of these subjects used expressions that seem to indicate that they organized the designs which they saw into groups of two or more. The following quotations, which include at least one from each of the twenty-three subjects just referred to, are presented as evidences of this process of grouping:

With reference to designs in the "vec" series:

"Another triangle with a straight line bisecting the angle."
"The same figure."
"Same principle we have been having."
"Another triangle with angle bisected."
"This one is out of the question, for it does not follow the others."
"Same figure.
"Same pattern."
"Same thing."
"These three belong to the same class, for there is a line down the center of each." [8]

With reference to designs in the "dax" series:

"Again, the same thing."
"There has always been one dot in the center and one on the outside."
"Evidently belongs to the same class."
"Similar to first and third."
"Still two dots and a circle."

With reference to designs in the "mib" series:

"Same type of thing."
"Similar to first ones."
"Triangle and line again."
"This figure shows the same thing."
"Another triangle with line cutting side."
"Same kind of object."
"The others have all been perpendicular to the base."

With reference to designs in the "zum" series:

"So far that seems to be the clue."
"Same condition."
"The same case here."
"All the same length, too."
"It's a good bit the same as the first one." [9]
"This is the same idea."

[8] The three figures referred to were the first ones in the series.
[9] The subject was examining the second design in the series.

TABLE 5

Showing the number of seconds spent in examining the designs (I), and the number of designs examined during that time (II), Experiment III

	Vec		Dax		Mib		Zum	
Subject	I	II	I	II	I	II	I	II
A	56	6	122	11	272	31	x	
B	223	53	188	39	x		x	
C	125	17	115	9	x		x	
D	79	9	160	12	77	10	x	
E	88	8	69	8	x		x	
F	69	5	68	7	x		x	
G	270*	19	135	13	x		x	
H	80	13	36	7	304	37	x	
I	87	16	56	17	x		x	
J	97	9	109	11	x		x	
K	119	9	58	6	x		257	18
L	30	6	35	7	x		x	
M	45	6	x		x		x	
Midscore	87		109					
Mean	105		96					

	Vec		Dax		M Mib		Zum	
Subject	I	II	I	II	I	II	I	II
N	64	10	72	11	x		x	
O	119	16	100	15	254	50	x	
P	100	16	77	17	x		x	
Q	352	64	155	32	x		x	
R	152	12	65	10	x		404	38
S	49	6	68	10	121	16	x	
T	177	27	87	17	x		x	
U	154	31	120	18	x		x	
V	143	18	110	20	x		x	
W	46	6	102	12	x		x	
X	56	6	57*	6	x		143	10
Y	178	6	164	9	x		x	
Z	87	7	169*	14	x		x	
Midscore	119		100					
Mean	129		104					

* Subject learned something from the test series.

Perhaps a few of these comments are merely a reflection of the instructions under which the subject was working, but it is exceedingly doubtful whether any considerable number of them can be adequately accounted for in such terms, especially since the same type of comments occurred in Experiment IV under instructions that made no reference whatsoever to any sort of "class" or "group."

Another result of this experiment which seems to us to be of some importance is the evidence which it furnishes of the presence of insightful behavior [10] in the process of concept formation. Two instances will be cited.

Subject K spent two minutes and fifty-seven seconds examining a total of twelve figures in the "zum" series, and then raised her hand. As her definition of "zum" she wrote, "A 'zum' is three lines of different lengths two of which are bisected by the third." (Apparently the subject meant "intersected" instead of "bisected," for the lines were not bisected in any one of the thirteen test figures after whose numbers she subsequently wrote "Yes," although they were intersected in each case.) The subject's drawings were defective, and she made a number of mistakes in going through the test series.

The subject spent three seconds reëxamining the figure last seen, pressed the contact key for a new figure, and approximately fourteen seconds later advanced the idea that the one line was trisected. About ten seconds thereafter, having examined another figure, she stated the generalization, "Three red lines, two of them dividing another into three equal parts." After examining four more figures, apparently with the idea of testing her

[10] We employ "insightful behavior" in preference to "insight" because it is a descriptive phrase that avoids the suggestion of faculty psychology. From our point of view, an individual exhibits "insightful behavior" when he makes complex discriminative responses which he could not make a relatively short time before, his physiological condition having remained relatively constant. Hunter uses "insightful behavior" and then discards it, apparently because it seems to him to suggest a distinct *kind* of learning. (Hunter, W. S. Experimental studies of learning. Chapter 15 in *The Foundations of Experimental Psychology*.) From the foregoing definition it will be seen that the phrase has no such connotation for us. From our point of view, however, it is a convenient device for rough classification (cf. "idiocy," "paranoia," and so forth).

hypothesis, the subject raised her hand. Then she wrote, " A 'zum' is three red lines of different lengths, two of which divide the third into three equal lengths or segments." She then made several drawings of " zum " that were accurate, and went through the series of test cards faultlessly.

Subject P spent one minute and thirty-one seconds examining a total of sixteen figures in the " zum " series, and then raised his hand. He defined " zum " as " Three red lines which cross each other but do not form an enclosed figure." His drawings were inaccurate, and he made errors in going through the test series.

Two minutes and fifty-one seconds were then spent by this subject in examining seventeen more designs. This time he defined " zum " thus: " Three red lines cross each other; the two shortest cross the longest." Again his drawings were defective, and his responses to the test series incorrect.

During the first fourteen seconds of the next learning period he reëxamined the design last seen, remarking that the majority of the designs were red. Then he pressed the contact key for a new figure, and several seconds later came out with the observation. " Two short lines seem to cut one line into three equal parts."

Hartmann has said that " We are now in the curious position where objectively more is known about insight in animals than in man." [11] Perhaps this is partly a matter of the vagueness of the term " insight." In any case, the two instances just given seem to us to illustrate that relatively rapid reorganization of response which we have called " insightful behavior."

The formulation, testing, and acceptance or rejection of hypotheses was seen again and again. Perhaps one instance will suffice. Subject S had been attempting to conceive of " zum " in terms of the relative lengths of the three lines. Then he took a new lead, for he made the observation, " The top angle is larger than the lower." He examined the next figure and said the same. He examined the following figure and said the same, adding, " That's promising." With his examination of the next figure came the remark, " Maybe it's the angles rather than the

[11] Hartmann, G. W. The concept and criteria of insight. *Psychological Review*, 1931, **38**, 252.

lines." This proved to be a blind alley, however, for not long thereafter, having examined several more figures, he confessed, "I'm lost."

As was to be expected, wide individual differences appeared in the number of figures examined per unit of time. Table 5 indicates that some of the subjects examined the designs at the rate of two or three per minute, whereas other subjects examined ten or more designs during the same period of time.

At times some of the subjects adopted a certain pace in their examination of successive designs, and held to it over a period of time.

As in the previous experiments, subjects who could go through the test series without error were often quite incapable of defining the concepts accurately. Of the fifty-nine definitions that accompanied a faultless test performance, twenty-three were defective.

Summary of Results

(1) There is no evidence that concept formation proceeds either more or less rapidly when the negative instances are far from fulfilling the conditions of the concept than when they violate only one condition essential to it.

(2) The process of concept formation appears to involve grouping. The learner tends to envisage certain stimulus patterns as constituting a group to which any given stimulus pattern does or does not belong.

(3) Insightful behavior seems to be present in at least some instances of concept formation.

(4) Concept formation, like most "thinking," appears to involve the formulation, testing, and acceptance or rejection of hypotheses.

(5) There are wide individual differences in the number of stimulus patterns examined per unit of time in concept formation.

(6) At times a subject may adopt a definite pace in his examination of successive stimulus patterns in concept formation.

(7) Further evidence is presented to the effect that one may have a concept and yet be quite unable to give an accurate verbal formulation of it.

CHAPTER VI

Experiment IV

This experiment was designed to attack the problem of the nature of concept formation, the approach being somewhat different from that employed in Experiment III.

The arrangement of apparatus was the same as in Experiment III.

One series each of "wez," "gid," "vec," "dax," "mib," and "zum" were used in this experiment. Ten of the designs in each series were regular figures; the other six were confusion figures. Three of these confusion figures violated only one condition essential to the concept in question; the other three violated two or more essential conditions. A plus sign was drawn under each regular figure, a minus sign under each confusion figure. The confusion figures were used because they seemed to make the learning truer to life situations.

The cards constituting a series, having been shuffled, were numbered in india ink immediately under their respective figures and placed in consecutive order on the drum.

Ten undergraduates and seven graduate students in psychology served as subjects in this experiment. Each subject came for two experimental periods. The following instructions were handed to him in typewritten form at the beginning of each period:

"You will see a series of geometrical designs or drawings. There are sixteen drawings in this series, and each drawing has its number under it. You will see them in order from one to sixteen. Each time you press the contact key (in front of you on the table) the next drawing in the series will appear.

"The apparatus operates in such a way that the series repeats itself indefinitely. Thus, drawing number 16 is followed by drawing number 1.

"Every design has either a plus sign or a minus sign under it. In the first series, each design that has a *plus* sign under it *is* a "wez," and each design that has a *minus* sign under it *is not* a "wez."

"*Try to find out what a "wez" is.*

"*When you think that you know what a "wez" is, raise your hand.*

"It is very important in this experiment that you *do all of your thinking out loud.* Imagine you are all alone and simply talking aloud to yourself.

"The experimenter will record the time that you take, but do not hurry. Take as much time as you need. Yet do not dally or hesitate overlong.

"After you have learned "wez," you will learn "gid," "vec," "dax," "mib," and "zum" (in this order) in the same way.

"Wez" and "gid" are merely illustrations.

"Please reread the above instructions until you are absolutely sure that you understand everything. If you do not see what is meant by any point, ask the experimenter about it."

Only one concept was true to all those designs in a series that were marked plus and at the same time false to all the designs in that series that were marked minus.

"Wez," "gid," and "vec" were learned the first experimental period, "dax," "mib," and "zum" the second. The subject was given only one trial (not to exceed five minutes) in the case of "wez" and "gid." In the case of the other concepts he was permitted to examine the figures for as much as, but no more than, seven minutes.

In general the results of this experiment support the conclusions reached in Experiment III concerning the nature of the process of concept formation.

As in Experiment III, a considerable number of quite varied expressions were used that seem to us to point clearly to the presence of grouping in concept learning. Quotations of comments of this sort, including at least one from each of eleven subjects follow:

With reference to designs in the "vec" series:

"Same kind of triangle, same position of line."
"Plus again."
"Equilateral again."
"Same kind of figure."

With reference to designs in the "dax" series:

"Same geometrical pattern.
"Still a circle with two dots, one inside and one outside."
"Same as first and third."

With reference to designs in the "mib" series:

"The same relationship is true here."
"Plus again."
"Same rule holds."
"Same type of triangle."
"Perpendicular to shortest side again."

With reference to designs in the " zum " series:

" Red again is the color of ' zum.' "
" They seem to be all the same thing."
" Here also."
" Same thing is true here."
" Same thing here."
" Same thing in each case."

These results seem to us to lend support to the view that grouping is present in most, and perhaps all, human learning.

A considerable number of instances of insightful behavior occurred in this experiment. Four of these will be cited.

Subject L spent approximately six and one-quarter minutes in examining the " mib " series and in formulating and rejecting theories concerning " mib." Toward the close of this period of time he was working on the hypothesis that the color and the angles were the essential conditions of " mib." As he put it, " It must be color and the angles." He was apparently working along these lines in the next four figures, to each of which he devoted five to ten seconds, for his comments concerned color. Several seconds after the exposure of the next figure, however, he asserted, " It's on the short side."

After approximately one minute and fifty seconds, during which time he had examined nine designs in the " mib " series, subject O said, " A short line attached to one side of a triangle either on the inside or the outside." He then pressed the contact key. Twelve seconds later he pressed the key again, and about ten seconds thereafter stated that " ' Mib ' seems to be a triangle with a line extending on the shortest side of the triangle." Approximately twenty seconds later, while examining another design, he said, " The line seems to make a right angle." His subsequent definition, drawings, and test performance were satisfactory.[1]

Subject C worked for four minutes and twenty-four seconds on the sixteen figures of the " zum " series, and then raised her hand. As a definition she wrote, " A ' zum ' is a figure consisting of two brown lines cut by another brown line." Her performance on the test series indicated that she did not know " zum." At the

[1] Later the subject said, " I noticed all of a sudden that it was the short side."

beginning of the next learning period she spent about fifteen seconds reëxamining the design last seen, pressed the contact key, and made the following comments relative to the next design: "This is a 'zum.' Two lines are unequal. They are brown. They divide the one line into equal parts." Subsequently she wrote, "A 'zum' is a straight brown line cut into equal parts by two other brown lines," made several satisfactory drawings, and went faultlessly through the test series.

After examining the "zum" series for three minutes and forty-four seconds, subject F wrote, "A 'zum' is a figure consisting of one red line cut by two red transversals at points such that the end segments on the original line are equal." Mistakes were made in going through the test series. For two and one-half minutes after learning was resumed, she commented on the transversals, pointing out that they were sometimes parallel, perpendicular to the third line, etc. "Transversals aren't equal," she said toward the close of the period of time just mentioned, and then pressed the contact key. She spent only four seconds on the next design, but during that time she made this significant remark: "Divides it into three equal parts." She examined a few more figures, raised her hand, and then wrote, "A 'zum' is a figure consisting of a red line cut by two red transversals in such a way that the three resulting segments of the original line are equal." Her drawings and test performance were also satisfactory.[2]

The conclusion reached in Experiment III to the effect that concept formation is to some extent a matter of the formulation, testing, and acceptance or rejection of hypotheses found abundant support in this experiment. A large number of examples could be mentioned, but the comments of K while learning "mib" will perhaps suffice. (Quotation marks enclose the comments relative to separate but successive figures.) "Is a 'mib.' Obtuse triangle with line perpendicular to one side. Let's see now, that line is perpendicular to the short side and is inside." "This is

[2] Later she said that the idea that the line was trisected "suddenly occurred to me all in a flash."

a 'mib.' Line is perpendicular to short side." "Here's a 'mib.' Line is perpendicular to short side." "Not a 'mib.' Line is perpendicular to long side." "Angle less than ninety degrees from long side." "Is a 'mib.' Line perpendicular to short side." "Same rule holds." "Same rule holds." "Same rule holds." "Same rule." "Same rule." While examining the next figure he raised his hand. (It will be recalled that this was the sign by which the subject indicated that he thought he knew what the concept was.)

Another result of this experiment was the evidence which it supplied of a correlation between intelligence-test performance and ability to learn concepts rapidly. As the best available measure of the latter, the exposure periods for "vec" and "dax" were added together. When the subjects were arranged in the order of the rapidity with which they learned these concepts and in the order of meritorious performance on the "Ohio State University Psychological Test" (in terms of percentiles), a rank difference correlation of $.52 \pm .125$ was found. Although such a correlation has a high coefficient of alienation, it may be regarded as suggesting a tendency.

As in Experiment III, there were wide individual differences in the rapidity with which the subjects examined the designs. Table 6, which shows the number of seconds spent in examining the designs and the number of designs examined during that time, gives ample evidence of this. In the case of "vec," for example, the five subjects who examined sixteen designs spent from seventy-three to 251 seconds in so doing.

At times some of the subjects adopted a certain pace in their examination of successive designs, and held it over a period of time. (This had been previously noted in Experiment III.)

As in the previous experiments, there were a number of instances wherein the subject's definition of the concept was defective, although his ability to go through the test series without error showed that he had learned the concept. Out of a possible forty-nine, eleven such cases were found in this experiment.

TABLE 6

Showing the number of seconds spent in examining the designs (I) and the number of designs examined during that time (II), Experiment IV

	Vec		Dax		Mib		Zum	
Subject	I	II	I	II	I	II	I	II
A	105	10	67	9	126	12	x	45
B	52	17	78	16	x	65	x	49
C	70	9	65	6	82	9	362	24
D	190	9	71	7	x	23	x	20
E	37	5	28	5	x	52	x	49
F	73	16	46	16	66	18	414	86
G	40	9	29	9	31	8	27	9
H	44	8	35	9	150	31	x	54
I	67	6	64	6	223	16	x	18
J	112	9	107	10	355	48	x	34
K	127	17	105	10	226	16	x	16
L	185	21	84	17	x	35	x	41
M	96	16	63	11	x	54	x	45
N	251	16	118	11	274	21	x	26
O	165	16	94	17	198	17	x	25
P	97	17	158	39	60	16	x	44
Q	107	16	63	6	94	10	x	44

Summary of Results

(1) It seems probable that ability to learn concepts rapidly is correlated positively with ability to make a high intelligence-test score.

(2) Items 2, 3, 4, 5, 6, and 7 in the "Summary of Results" at the end of Chapter V are supported by evidence obtained from a type of approach somewhat different from the one reported therein.

CHAPTER VII

Conclusion

The recognition of the problem of concept formation goes back at least as far as Plato. However, men have for the most part followed this philosopher in placing the problem outside the sphere of natural science, thereby making it possible to talk at length without the danger of being opposed by a recalcitrant fact.

When this problem was finally investigated in the laboratory, it was at first distorted by the use of an introspective technique, and then, in a reaction against the introspective approach, oversimplified by the use of a technique designed to make for the discovery of " common elements." This latter approach has a real place in a natural-science psychology, but it is in connection with purely analytic processes. Concept formation is not such a process, for it is both analytic and synthetic. An adequate approach to it must take cognizance of this and use a type of stimulus pattern that is a dynamic whole, not a mere camouflaged " element." For the *sine qua non* of concept formation is response to relationships, not to some bare " element."

This was the cornerstone of theory on which the present study was constructed. It found expression at the very outset in the choice of learning material.

Once this choice had been made and the ten concepts developed, two questions immediately arose: (1) Are the designs in question suitable for studies of concept formation? (2) What is the relative difficulty of the concepts? These could be answered only by an appeal to experimentation. Experiment I was the result. It showed that most of the designs could be used as material for concept learning and that certain of the concepts were relatively difficult, whereas others were relatively easy. It also indicated that individuals who have learned concepts, in the

sense of being able to make consistently correct discriminations while going through a crucial test series, frequently fail to define these concepts with accuracy. This occurred again and again in subsequent experiments.

All of the designs used in the first experiment had been positive instances of, *i.e.* true to, the concept in question. What would happen if negative instances of the concept, *i.e.* designs false to it, were introduced? Experiment II suggested that negative instances are not necessarily aids to rapid learning. Some subjects did appear to learn from them, it is true, but others seemed to find them a waste of time or even a source of confusion. However, there was no evidence of two or more rigid "types." The evidence suggested the possibility that further experimentation might find learners scattered in a form approximating a bell-shaped curve, most individuals learning something from negative instances and a progressively smaller number of individuals approaching the extremes of learning everything or nothing from them.

The negative instances in Experiment II had violated only one condition essential to the concept. What would happen if two or more conditions were violated? Experiment III was designed to throw some light on this question and at the same time to reveal something of the nature of the process of concept formation. Negative instances that violate more than one condition essential to the concept do not make for either more or less rapid learning than those that violate only one essential condition, this experiment seemed to show. It also pointed to the presence of a number of factors in concept formation, the most significant being these: grouping, insightful behavior, and formulation, testing, and acceptance or rejection of hypotheses.

In view of the complexity of, and the consequent need for a number of different approaches to, the process of concept formation, it was deemed advisable to perform a new experiment the results of which would serve as a check upon the conclusions reached in Experiment III regarding the nature of the process of concept formation. Experiment IV was designed in such a way

that instead of having the subject build the concept from the ground up, as he did in Experiment III, he was presented with stimulus patterns which were marked so as to indicate whether or not they were true representations of the concept to be learned. The same factors that operated in the concept formation that occurred under the conditions prevailing in Experiment III were found to be operative here. Experiment IV also suggested that there is a positive correlation between ability to learn concepts rapidly and ability to make a high intelligence-test score.

If the view of concept formation which we have presented is sound, the learning that took place in these experiments was true to the learning that occurs in the workaday world. This is not to assert that the conclusions reached in these experiments are forever applicable to *all* concept learning. In all probability they are not.[1] But it does suggest that the type of learning involved here was not a mere laboratory construct—that it was real in the same sense in which any learning is.

Most of the significant learning situations that normal human beings face involve concept formation, and yet our knowledge of this all-important process is small indeed. This study is presented in the hope that it suggests an adequate envisagement of the problem and some techniques that may prove to be of value in its solution.

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[1] For example, some of our conclusions may not be applicable to those numerous instances of concept formation that involve manipulation of the learning material and knowledge of the use to which the object can be put.

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